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Rural forested areas as an only background for regional carbon and environmental balance

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Abstract

Techno systems release CO_2 meanwhile natural ecosystems accumulate it in biomass and these flows for total techno-ecosystem stability should be in quantitative balance. General environmental stability (GES) may be described as ratio of total amount of carbon sequestered (TACS) annually by forested area of region to total amount of carbon (TACR) released on the same area from industrial sources. For Leningrad region this ratio is estimated as much as 1.15 and we may generally conclude about enough productivity of local forest ecosystems to accumulate locally released anthropogenic carbon and therefore about positive input of Leningrad region into global carbon cycle.

Key words

forested area, carbon sequestration, gross primary production, net primary production, respiration.

Introduction

Because urbanized territories are consequently increase in area for all over the world countries it is reasonable introduce such a term – techno-ecosystem consisting of two general parts: natural ecosystems and techno systems. These two compartments are very close and complexly connected by a number of material and energy flows but now one of them, carbon flow, is of priority importance. Techno systems release CO_2 meanwhile natural ecosystems mainly accumulate it in biomass and these flows for total techno-ecosystem stability should be in quantitative balance (Fig. 1).

If for some region natural ecosystems per year accumulates the amount of CO_2 equal or more generated by techno system on the same area for same year we may conclude positively about general environmental situation here. Amount of carbon sequestrated by forest ecosystems depends on size and productivity of forested lands of region the more these both the better regional environmental status.

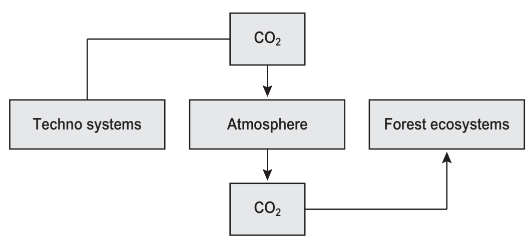

Fig. 1. Analyzed techno-ecosystem carbon flows

The main aim of this paper is to couple the main-made and natural carbon flows on balance approach and provide the methodology on how use the forest inven-

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tory data for integrated environmental assessments on regional level.

Methods and data

Based on this balance it is possible to use such main forested land inventory characteristics as area and mean annual increment as well as information on species composition, biomass composition, species wood and other fractions density for estimation of general environmental stability of analyzed region. General environmental stability (*GES*) may be described as ratio of total amount of carbon sequestered (*TACS*) annually by forested area of region to total amount of carbon (*TACR*) released on the same area from industrial sources:

$$GES = \frac{TACS}{TACR}$$

If *GES* more or equal to1 then the region may be considered as environmentally stable in general from carbon cycle point of view and even input positively into global stability (if *GES*>1).

We consider the total amount of carbon (*TACS*) accumulated annually in forest ecosystems as equal to gross primary production (*GPP*):

$$GPP = NEP + R + R_g,$$

where *NEP* – net ecosystem production, *R* and R_g – autotrophic and heterotrophic respiration respectively. We consider the *GPP* value as a good integrated indicator of ecosystem vitality despite of the mean age of forest component which directly determine the *NEP,* usually considered as more valueable from carbon cycle point of view. For example, in old growth forest *NEP* may be very close or even equal to zero meanwhile *GPP* is big and therefore large amounts of carbon annually goes through forest ecosystem biomass and returns to the atmosphere as natural, not man made carbon emission (Alekseev and Selikhovkin 2006).

Unfortunately the data on R_g is not collected during regular forest inventory and therefore is very poor. From other hand, the estimation of R_g based on well known literature data (Whittaker 1975, Odum 1983, Margalef 1992, Beagon *et al.* 1986,) gives the values as much as 2-3% of *GPP* that is why as a first approximation for further analysis we will consider only primary productivity of forest ecosystems.

So, based on the above rationale total amount of carbon sequestered (*TACS*) annually by forested area may be calculated by following formula:

$$TACS = GPP = NPP + R =$$
$$= \sum_{i=1}^{n}\sum_{j=1}^{m} S_{ij} \times \sum_{k=1}^{l} C_{ijk} \times d_{ijk} \times I_{ijk} + R,$$

where, *GPP* – gross primary production, t/hectare*year; *NPP* – net primary production, t/hectare*year; *R* – autotrophic respiration, t/hectare*year; S_{ij} – area covered by forest of species *i* at age *j*, hectares; C_{ijk} – share of carbon in absolutely dry fraction of biomass *k* of species *i* at age *j*; d_{ijk} – content of absolutely dry matter (density) in fraction of biomass *k* of species *i* at age *j*, t / m^3; I_{ijk} – volume increment of fraction of biomass *k* of species *i* at age *j*, m^3/hectare*year.

As it easy to realize the above formula for *TACS* represents the carbon accumulated in gross primary production of regional forests including both, net primary production (*NPP*) and also the carbon meanwhile goes through forest biomass and later released back to atmosphere by biomass respiration (*R*). This last carbon after it goes through forest biomass becomes natural and also should be included into annually sequestered amount *TACS* as a characteristic of forest vitality and carbon exchange ability. Forest biomass respiration "laundered" the man-made carbon. The data, part of which represented in table 1 is of help in calculations of *GPP*.

Respiration of forest stands was estimated on the base of special balance model (Alekseev 1992):

$$GPP_t = NPP_t + R_t; (1)$$

if we define

$$R_t = a*GPP_{t-1},\ GPP_t = k*NPP_{t-1}$$

then balance equation (1) may be presented as

$$NPP_t - k \times NPP_{t-1} + a \times k \times NPP_{t-2} = 0.$$

Last equation offers us a possibility to determine parameters *a* and *k*, and therefore GPP_t and R_t on the basis of time series of NPP_t only. The results of calculations of gross primary production (*GPP*), net primary production (*NPP*) and autotrophic respiration (*R*) for

forest tree stands of main species at the age 50-years old are presented in the table 1 (Alekseev 1992).

Tab. 1. Gross primary production (*GPP*), net primary production (*NPP*) and autotrophic respiration (*R*) for forest tree stands of main species at age 50-years old, t/hectare*year of absolutely dry matter

Species, growth class	*GPP*, t/hectare* year	*NPP*		*R*	
		t/hectare* year	%	t/hectare* year	%
Norway spruce					
I	10.0	6.1	61	3.9	39
II	9.6	4.9	51	4.7	49
III	7.9	4.6	58	33	42
IV	6.3	4.5	71	1.8	29
V	5.6	3.7	66	1.9	34
Scots pine					
I	9.5	5.8	61	3.7	39
II	9.2	5.1	55	4.1	45
III	8.6	5.0	58	3.6	42
IV	7.1	4.6	65	2.5	35
V	6.0	4.1	68	1.9	32
Birch					
I	11.6	6.7	58	4.9	42
II	10.6	6.0	56	4.7	44
III	9.5	5.5	58	4.0	42
IV	9.8	4.9	50	4.9	50
V	5.6	3.7	66	1.9	34

Results and conclusions

We apply the developed theory for Leningrad region to couple man-made and natural carbon flows in order to produce integrated environmental estimation of carbon cycling on the area and to answer on the question – is productive capacity of Leningrad region forests enough to sequester all annually released anthropogenic carbon?

The above formula components not so easy to determine for any regional ecosystem that is why as a fist approximation may be used officially reported forest inventory and environmental data. For Leningrad region including city of Saint-Petersburg the TACR estimated as much as 29 millions tons CO_2 per year, which corresponds to 7.91 millions tons *C* per year.

TACS for the same area may be estimated using officially reported figure on total mean annual wood increment of all species which is as much as 13.64 millions of cubic meters per year or approximately 2.73 millions tons *C* per year, conversion coefficients of biomass fractions and data on autotrophic respiration. These gives the TACS as much as 9.1 millions tons C per year and GES = 1.15 or 115%.

GES calculated on the basis only NPP and only stem wood biomass annual increment are equal to 69 and 34% respectively. Including of R – autotrophic respiration into analysis of carbon sequestration by regional forest biomass is of principal significance because may alter the final conclusions, for example, GES based on NPP only and equal to 69% shows not enough forest ecosystem productivity to balance anthropogenic carbon flow, meanwhile accounting for R gives the opposite result.

We are believe that despite respiration carbon comes back to the atmosphere its status after coming through forest biomass changes from anthropogenic to natural and this carbon should be accounted for as a part of total amount of carbon naturally sequestered annually by living forests. If so, we may generally conclude about enough productivity of local forest ecosystems to accumulate locally released anthropogenic carbon and therefore about positive input of Leningrad region into global carbon cycle. Last may be considered as an integrated regional environmental assessment.

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